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STATUS OF COLUMBIA RIVER BLUEBACK SALMON RUNS, 1951

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 74

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Explanatory Note

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Washington, D. C.
April, 1952

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United States Department of the Interior, Oscar L. Chapman, Secretary
Fish and Wildlife Service, Albert M. Day, Director

STATUS OF COLUMBIA RIVER BLUEBACK SALMON RUNS, 1951

by

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Special Scientific Report: Fisheries No. 74

The commercial take of blueback salmon in 1947 exceeded all catches since 1926 and the escapement (count of fish over Bonneville Dam minus the catch above Bonneville) was the largest since counting was started at Bonneville in 1938. This large escapement caused West Coast fishery agencies to become concerned about the capacity of the limited remaining stream areas to accommodate the larger number of spawners. A survey was therefore made to determine the density of populations and the probable success of natural spawning of blueback salmon utilizing the remaining rearing grounds in the Wenatchee and Okanogan River systems.

The earlier parts of this work were done at the direction of Joseph T. Barnaby, formerly Chief, North Pacific Fishery Investigations. Ralph P. Silliman was in charge of the first field surveys. Grateful acknowledgement is due Floyd G. Bryant, A. A. Gentry, Zell E. Parkhurst and K. G. Weber for their active participation and helpful suggestions in the preparation of this report.

A BRIEF HISTORY OF COLUMBIA RIVER BLUEBACKS

The blueback salmon (O. nerka), unlike other salmon, generally deposits its eggs in streams tributary to lakes or on the shores of lakes themselves. On emerging from the gravel, the young usually spend one or more years in the lake before making the seaward migration. Most lakes suitable for propagation of bluebacks have been lost through the development of power and irrigation projects. High dams without fish facilities, and irrigation canals without proper screening for downstream migrants, have combined to deplete the rearing areas (Rich 1942, p. 106).

The known blueback spawning areas (figure 1) of the Columbia River system, have never been as numerous as those for the chinook salmon. They include the Payette and Redfish Lakes in Idaho, Wallowa Lake in Oregon, the lakes of the Yakima River system in Washington, and the Arrow and Upper Okanogan Lakes in Canada, all of which have been isolated by dams.1/

The last of these systems to be eliminated, the Arrow Lakes, was isolated by Grand Coulee Dam. To compensate for the loss of spawning area the U. S. Bureau of Reclamation built three hatcheries and financed relocation of bluebacks and other species of fish. All bluebacks were placed in two remaining spawning and rearing areas, (1) the Lake Wenatchee region in central Washington, and (2) Lake Osoyoos which lies in Canada and north central Washington (Fish and Hanavan 1948, p.5).

1/ The Redfish Lakes are now accessible, but the runs had already been depleted by Sunbeam Dam and have never been restocked. Surveys in the area during the 1946 and 1947 seasons revealed only six bluebacks.

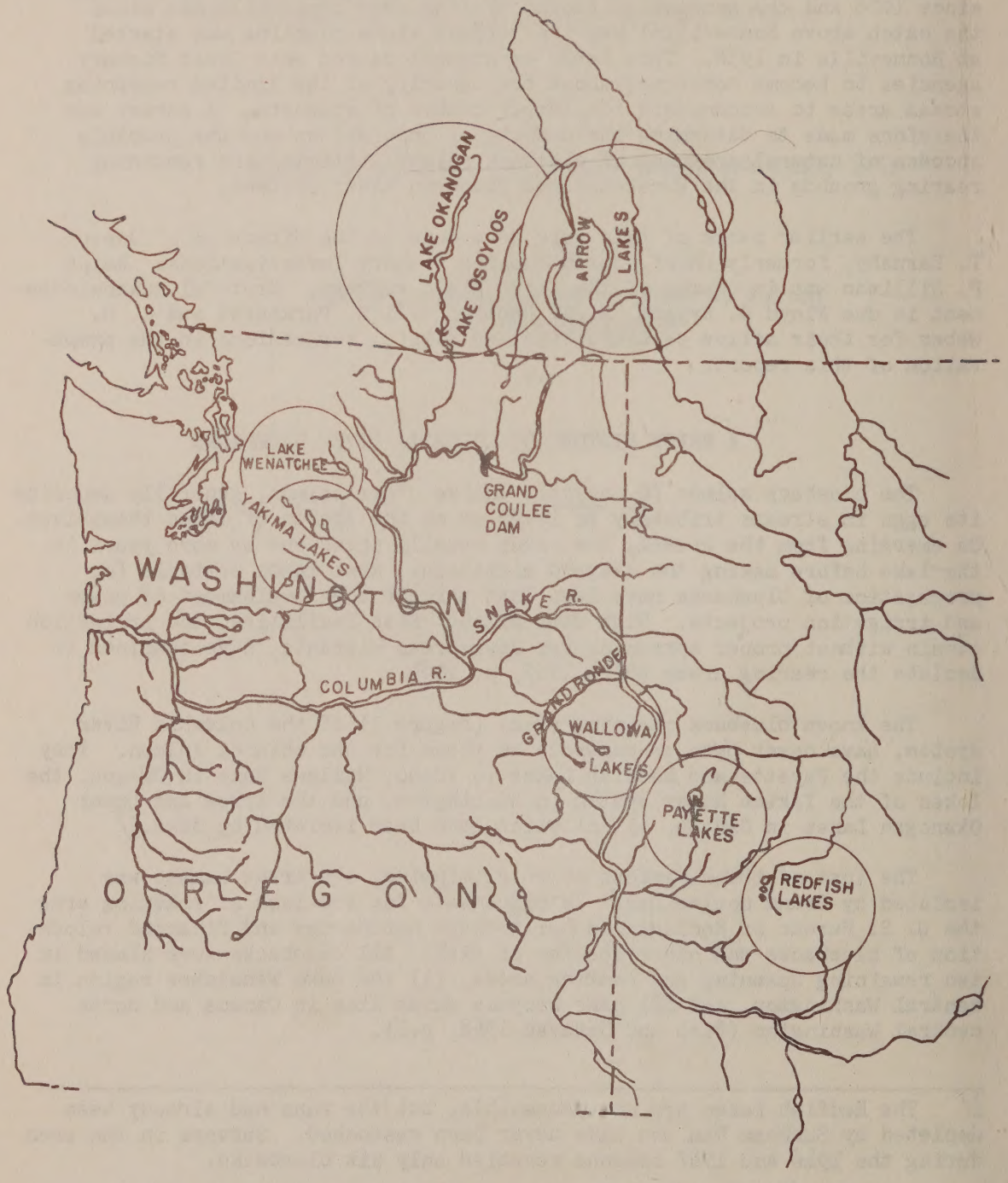

Figure 1. Known blueback salmon rearing areas of the Columbia River System--past and present

Paralleling the decrease of available spawning and rearing areas for the bluebacks has been the decline of the commercial catches of blueback salmon. This is illustrated in figure 2 and shows early catches of 1 million pounds to be common, with occasional takes exceeding 4 million pounds (Craig and Hacker 1940, p. 198). Wide fluctuations occurred in the commercial fishery but a distinct downward trend persisted until a low of only 8,500 pounds was taken in 1945.

PRESENT STATUS OF BLUEBACK RUNS

Since the Grand Coulee Fish Salvage Project of 1939-43, the blueback runs have shown evidence of recovery. This may be a result of special effort in connection with the salvage program (Fish and Hanavan 1948, p.51), or may be merely a natural fluctuation such as those which occurred before the Grand Coulee Dam was built.

In their spawning migration blueback salmon must pass over Bonneville and Rock Island Dams (figure 3) where counting stations are maintained. The counts of salmon over the two dams on the migration route to the spawning grounds help considerably in an analysis of the runs. Information obtained from the States of Oregon and Washington on daily deliveries of blueback salmon to canneries enables us to complete the picture of the trends of abundance of the species.

An example of the runs analysis derived from the available information is seen in table 1. Inspection of the Rock Island Dam precentage of escapement (item 13) reveals considerable fluctuation from year to year. This is probably due to three factors: (1) low water conditions and resulting higher temperatures causing mortality2/, (2) natural mortality of fish infected with disease or otherwise in a weakened condition, and (3) straying into other streams. The percentage of fish at Rock Island Dam does appear to be increasing, however, as shown in table 1.

Item 11 in table 1 gives fishing intensity which is calculated by dividing the total commercial deliveries by the total estimated run. It can be seen that there is a wide variation in fishing intensity, which ranges from 13.5 to 89.3 percent. The 1948 and 1949 rates of fishing intensity were low due to a closure of commercial fishing during the major part of the blueback migration, the purpose of the closure being to obtain a larger spawning escapement so as to increase future runs of fish.

2/ The extremely small percentage of bluebacks reaching Rock Island in 1941 was caused by extreme low water conditions aggravated by a water shortage as a result of the filling of Grand Coulee Reservoir. Low water caused lethal temperatures and provided poor passage over artificial and natural barriers in the river (Fish and Hanavan 1948, p. 51).

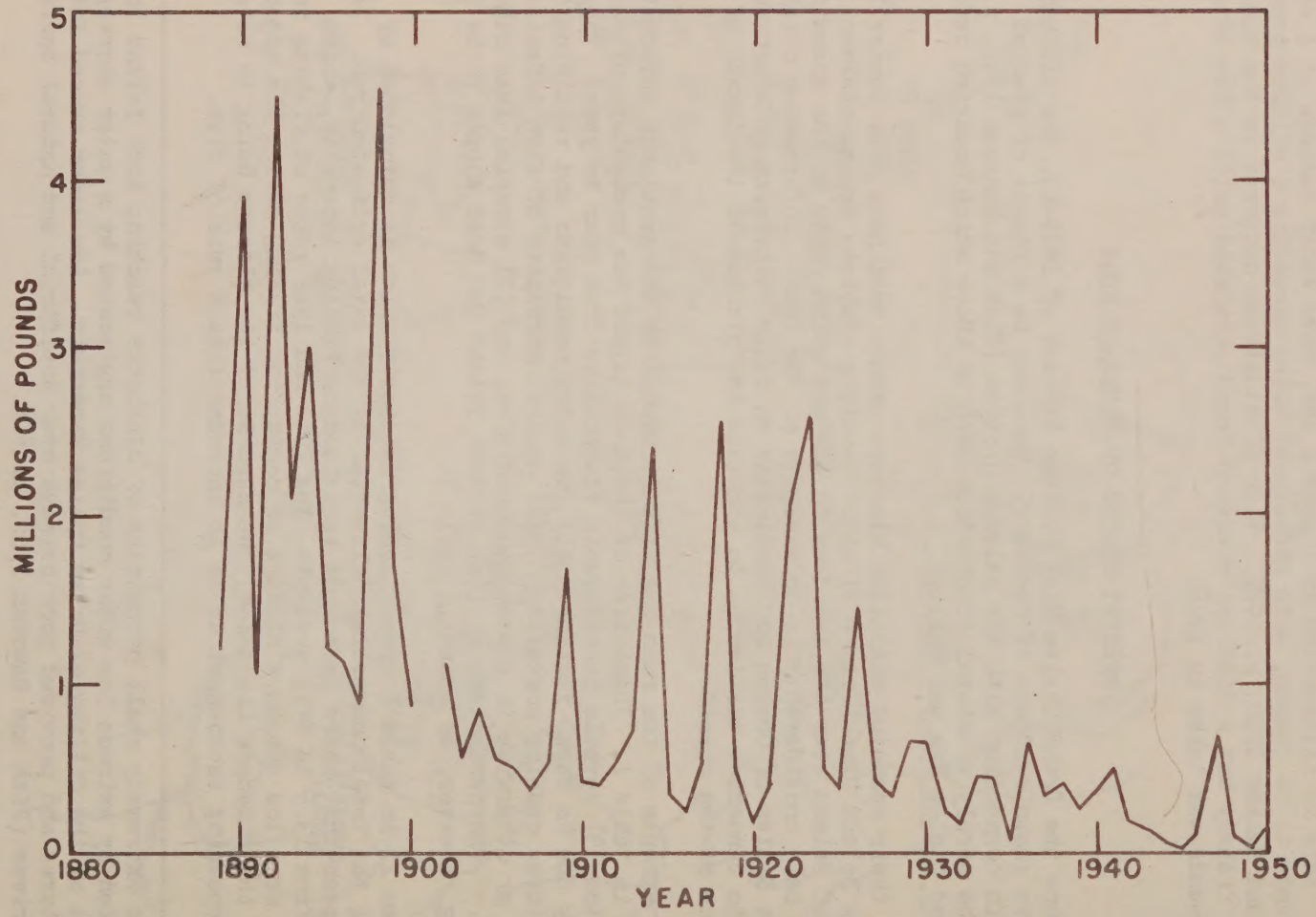

Figure 2. Commercial catches of blueback salmon, Columbia River, 1899-1950

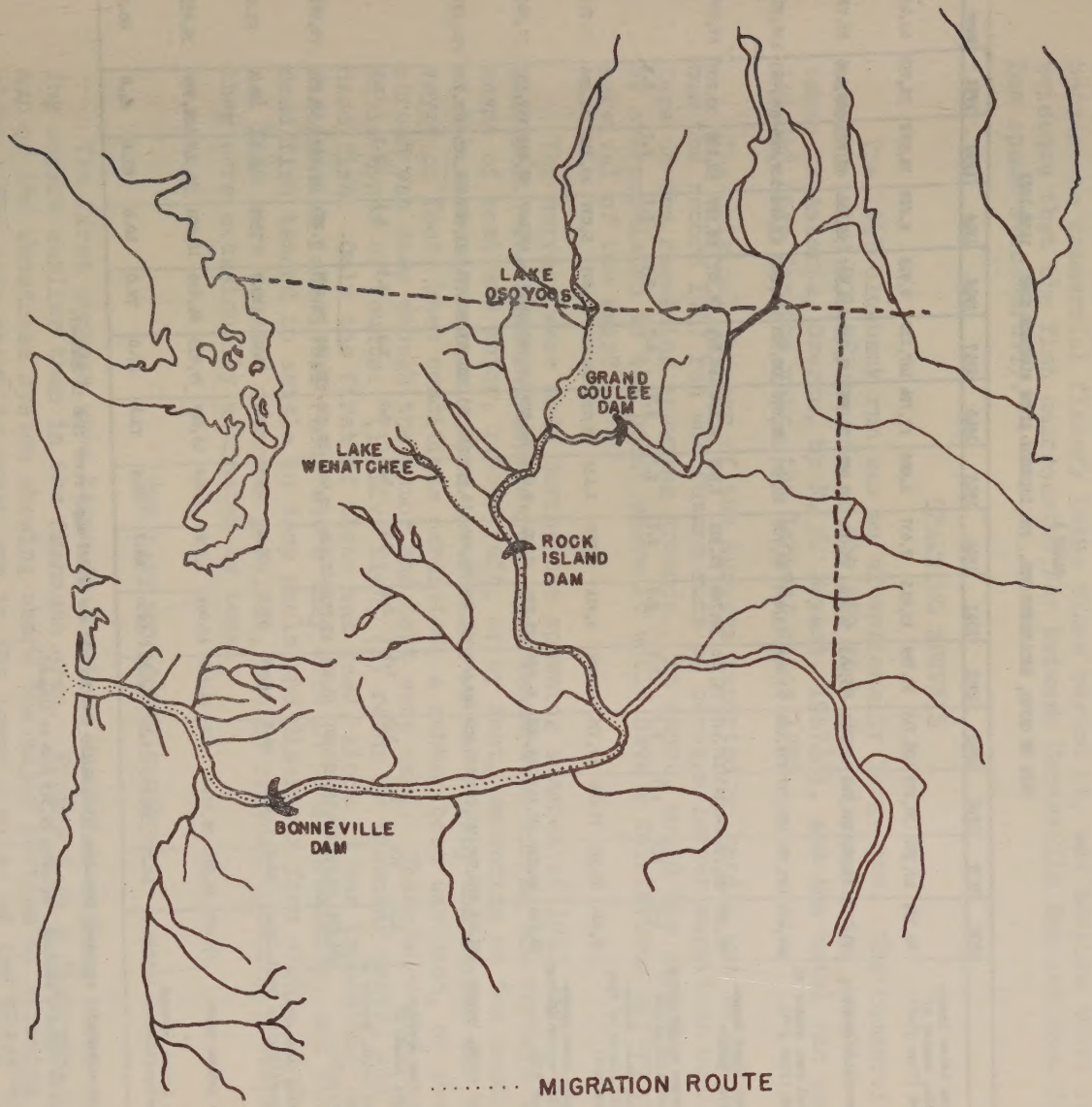

Figure 3. Present known migration routes of blueback salmon, Columbia River System.

TABLE 1

DATA ON CATCH, ESCAPEMENT ETC., FOR COLUMBIA RIVER BLUEBACK RUNS - 1938-1951

ITEM	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	Mean
(1) Catch below Bonneville, number of fish (Item 10-6)	92,374	47,384	36,972	105,715	37,799	33,813	7,637	1,096	27,724	167,110	8,915	2,222	31,952	35,955	45,476
(2) Bonneville count	75,040	73,382	148,805	65,741	55,463	39,844	15,071	9,801	74,354	171,236	131,537	51,444	77,993	169,428	89,771
(3) Total run, number of fish (Item 1+2)	167,414	120,766	185,777	171,456	93,262	73,657	22,708	10,897	102,078	338,348	140,452	53,666	109,945	205,383	128,251
(4) Catch above Bonneville, pounds	98,398	90,105	196,193	127,915	55,362	26,768	21,321	3,869	35,194	140,594	58,327	13,599	52,138	33,200 3/	68,070
(5) Average weight above Bonneville, pounds 1/	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	
(6) Catch above Bonneville, number of fish (Item 4/5)	36,444	33,372	72,664	47,376	20,504	9,914	7,897	1,433	13,035	52,072	21,603	5,037	19,310	12,296	25,211
(7) Escape above Bonneville, number of fish (Item 2-6)	38,596	40,010	76,141	18,365	34,959	29,930	7,174	8,068	61,319	119,166	109,934	46,407	58,683	157,132	57,563
(8) Total catch, pounds	425,100	266,500	361,800	505,200	192,400	144,300	55,921	8,597	126,353	701,383	95,794	23,954	169,163	159,228	231,121
(9) All-river average weight pounds 2/	3.3	3.3	3.3	3.3	3.3	3.3	3.6	3.4	3.1	3.2	3.3	3.3	3.3	3.3	
(10) Total catch, number of fish. (Item 8/9)	128,818	80,756	109,636	153,091	58,303	43,727	15,534	2,529	40,759	219,182	29,028	7,259	51,262	48,251	70,581
(11) Fishing intensity, percent(100xItem 10/3)	76.9	66.9	59.0	89.3	62.5	59.4	68.4	23.9	39.9	64.8	20.7	13.5	46.6	23.5	55.0
(12) Rock Island count	17,123	19,591	26,894	949	16,282	17,665	4,932	7,142	45,029	79,833	84,626	18,601	50,047	101,782	35,035
(13) Rock Island percent of escape(100xItem 12/7)	44.4	49.0	35.3	5.2	46.6	59.0	68.7	88.5	73.4	67.0	77.0	40.0	85.2	64.8	60.9

1/ Based on Bryant's sampling, including 3,031 Celilo fish in 1947 and 19,822 upper river fish in 1944-47.

2/ Based on Bryant's sampling, including 29,343 fish in 1944-47.

3/ Preliminary estimate.

The dam counts and total runs analysis is illustrated in figure 4, in which it can be seen that since the low of 1945, the runs have shown signs of recovery. Since bluebacks are predominantly 4 years old at time of return, the counts in figure 5 are plotted by 4-year cycles. Of particular interest is the marked increase of bluebacks passing Rock Island Dam. The count there probably represents the best measure of the spawning escapement, because no commercial fishery takes place beyond it, and because there is no evidence that the fish unaccounted for between Bonneville Dam and Rock Island Dam spawn successfully.

SPAWNING SURVEYS

The 1947 blueback run was an exceptionally large one. The commercial catch totaled 701,383 pounds or 219,182 fish (based on average weights taken in Astoria, Oregon, by F. G. Bryant, 1947[3/]), and the total run was 338,348 fish for the year, the largest since 1926.

The original purpose of the surveys reported on herein was to determine how the record 1947 run and future runs of perhaps larger magnitude would fare on the remaining spawning grounds. In short, would the spawning gravels be overpopulated to the point where it would have a deleterious effect on the survival of the eggs?

The surveys were made during the spawning seasons of 1947, 1948, 1949, and 1951. The spawning populations were enumerated during the surveys by means of boat and motor, rubber raft, or by foot, depending on the condition of the various streams. When too shallow or too swift, the stream was surveyed on foot. When conditions permitted, a rubber boat was used, or when the stream was deep enough the motor and boat were used. There were three possible types of counts: (1) Live fish, (2) redds or spawning nests, and (3) dead fish. Only the first of these was used, since it was impossible to distinguish individual redds where they were in close proximity, and since dead fish tended to settle in deep pools and disappear from sight. Individual fish were counted whenever possible, but on crowded spawning gravels they were occasionally estimated by tens.

THE LAKE WENATCHEE SURVEYS

The first surveys were begun in the Lake Wenatchee region, where spawning occurs earlier than in the Okanogan area. Figure 6 is a diagrammatic map of the Wenatchee system showing where the major portion of spawning takes place. The main spawning areas are in the lower 2 miles of the North Fork of the White River and the main stem of the White River from the North Fork downstream to within 2 miles of Lake Wenatchee. Blueback spawn in the Little

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3/ "Average Weights of Columbia River Salmon". 1947, Floyd G. Bryant, unpublished report.

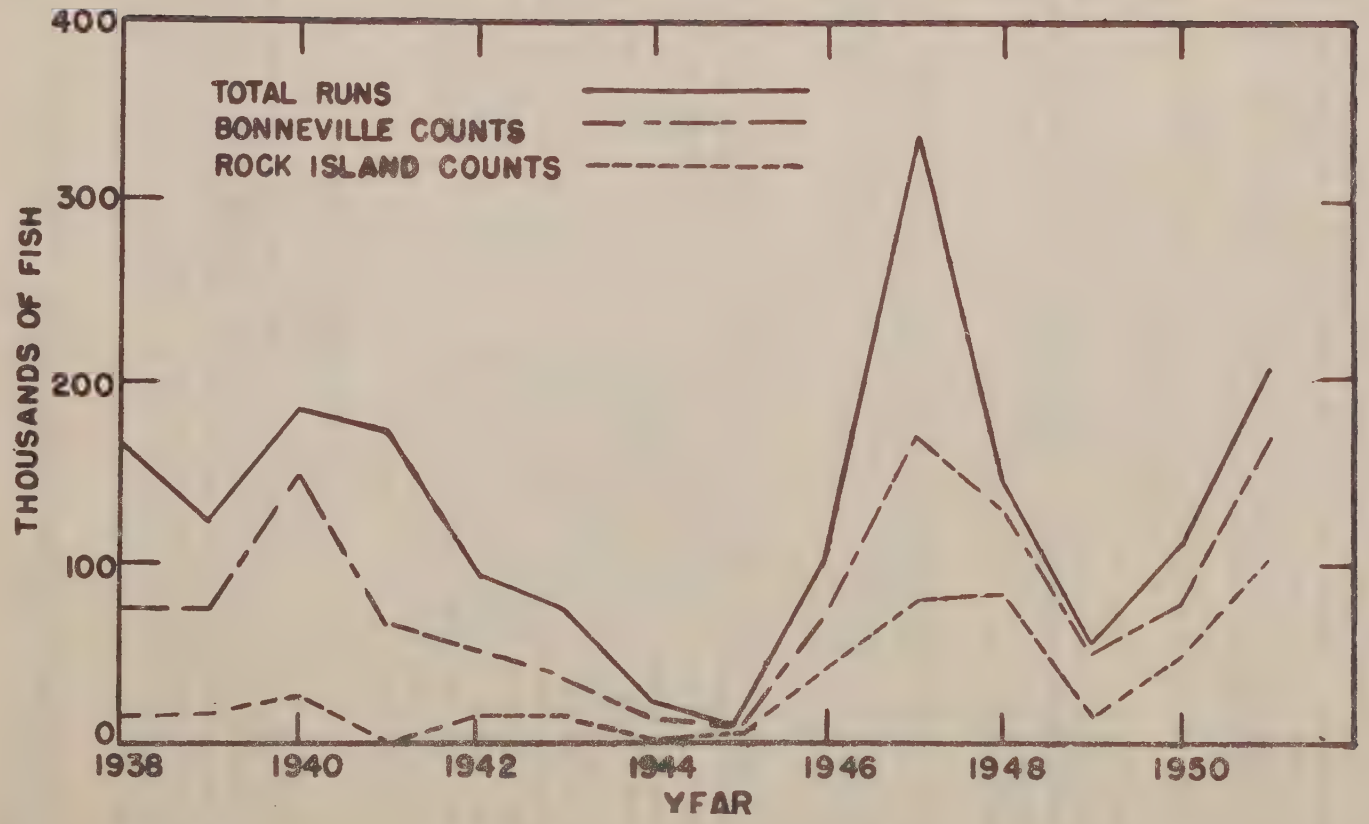

Figure 4. Columbia River blueback salmon counts over Bonneville and Rock Island Dams and total run data 1938-51.

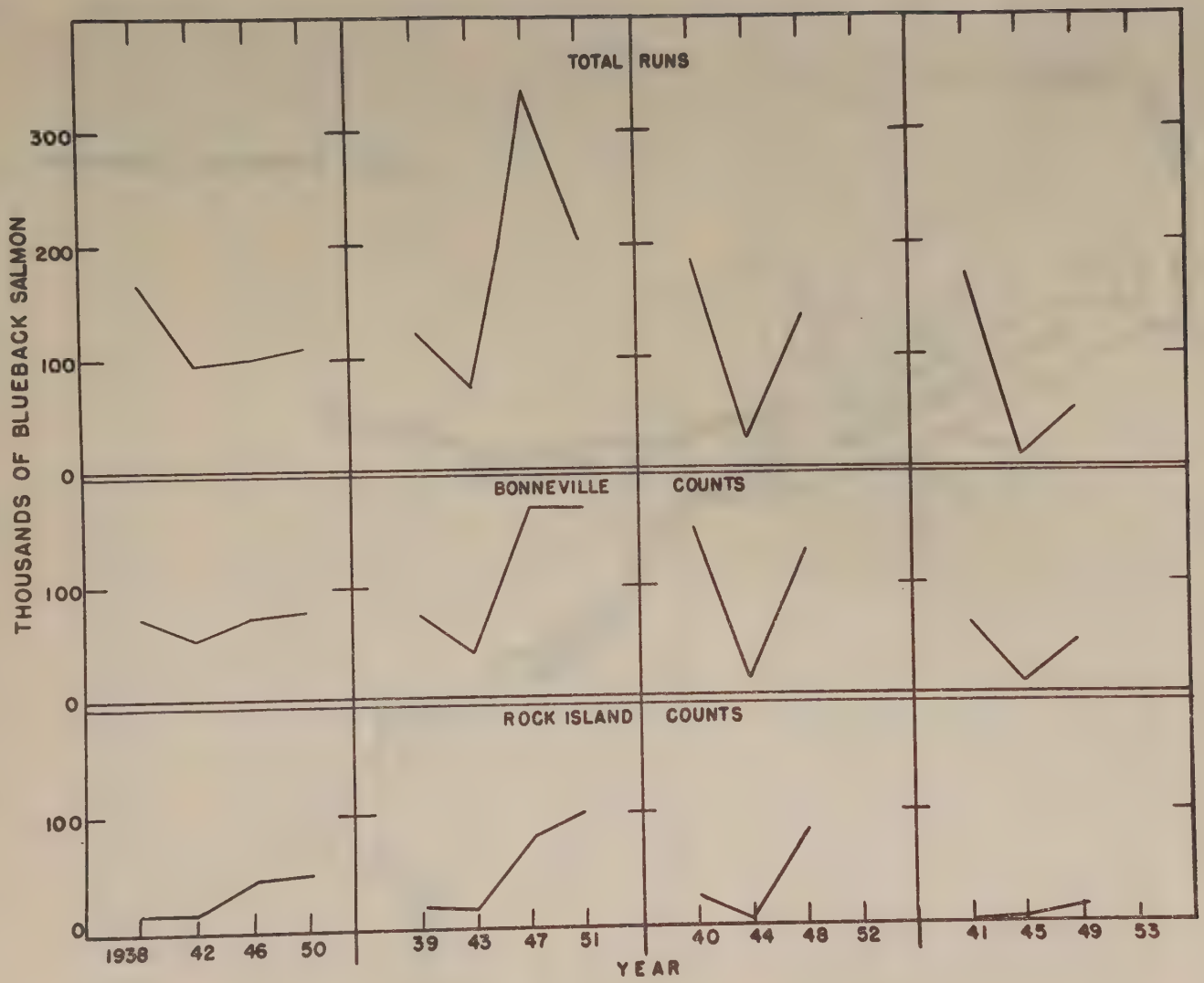

Figure 5. Columbia River blueback salmon counts over Bonneville and Rock Island Dams and total run data 1938-51 plotted by 4-year cycles.

Figure 6. Diagrammatic map of the principle blueback salmon spawning areas of the Lake Wenatchee System.

Wenatchee River throughout its lower 7 miles except for a short stretch near the lake. A 1/2-mile reach at the outlet of Lake Wenatchee, and the lower 2 miles of Nason Creek are used also. Smaller spawning populations scatter down the Wenatchee River to the town of Plain. Two areas on the shore of Lake Wenatchee where underwater seepage enters the lake are used also.

Tow of these spawning-stream sections are downstream from the lake. It was once thought that all bluebacks proceed through a lake in their migration and spawn in the lake's tributaries; however, bluebacks are seen spawning below Lake Wenatchee each year. Scale samples taken from these spawners revealed a freshwater life history no different from those taken from above the lake, suggesting that they were hatched above the lake, or migrated upstream to it shortly after hatching. On further inquiry, it was found that this anomalous behavior is quite common in Karluk and Bristol Bay, Alaska, and also in sockeye (blueback) streams in Canada. The chances of survival of the resulting young fish are questionable. If they could swim back up into the lake, their chances of survival would be equal to the chances for survival of fry hatched in streams above the lake. But if they proceed to sea shortly after attaining the free-swimming stage, there is a fair indication, not to be taken as conclusive, that they would experience a mortality far in excess of those which migrated in their second and third years (Gilbert 1912, p. 61).

The procedure for making the spawning surveys was to enumerate the fish in each section of stream periodically until the peak of the run had been observed in each instance. Some stream conditions influenced the accuracy of the counts. For example, the North Fork of the White River and the main stem below become very turbid after a rain storm and poor visibility is the result. Also flooding conditions in the Osoyoos region in 1948 made counts in the major portion of the stream impossible.

The maximum counts made in various streams appear in table 2. In an attempt to account for the total number of fish utilizing each section of stream, certain estimates can be made provided the necessary assumptions are made also. The maximum counts in each spawning section will give an absolute minimum estimate because we know that many successive groups of fish utilized the spawning gravel in the course of the spawning season. This does not, however, account for the total number of fish utilizing the various spawning grounds but merely represents the "standing crop" of spawners, which during the entire spawning period are being added to by late arrivals and diminished by dying spawned-out salmon.

The counts (table 2) for the four survey years, when the hatchery-spawned bluebacks and maximum stream counts are added, total 12,178 in 1947, 16,209 in 1948, 2669 in 1949, and 7,089 in 1951 for the Wenatchee area, compared with Rock Island counts of 79,833, 84,626, 18,601, and 101,782.

TABLE 2

STREAM CENSUS OF BLUEBACK SPAWNERS USING MAXIMUM COUNTS,

WENATCHEE RIVER

Stream	Section	Date	Max. Count	Total
	1947			
White River	North Fork 2 mi. above confluence	9/24	58	
	Confluence to lake	9/17-19	5,529	
Little Wenatchee River	Lake to hatchery rack	9/18	1,122	
Nason Creek	Cole's Corner to the Wenatchee R.	9/22	482	
Wenatchee River	Outlet of lake to ½ mile below	9/22	1,082	8,273
Little Wenatchee	Hatchery take			3,905
				12,178
	1948			
White River	North Fork 2 mi. above confluence	9/17	3,400	
	Confluence to lake	9/21	3,871	
Little Wenatchee River	Lower seven miles	9/14	2,701	
Nason Creek	Cole's corner to the Wenatchee R.	9/17	478	
Wenatchee River	Outlet of lake to ½ mi. below	9/15	1,594	12,044
Little Wenatchee	Hatchery take			4,165
				16,209
	1949			
White River	North Fork 2 mi. above confluence	9/27	265	
	Confluence to lake	9/21	659	
Little Wenatchee River	Lake to hatchery rack	9/20	248	
Nason Creek	Cole's corner to the Wenatchee R.	9/14	70	
Wenatchee River	Outlet of lake to ½ mi. below	9/21	196	1,438
Little Wenatchee	Hatchery take			1,231
				2,669
	1951			
White River	North Fork 2 mi. above confluence	9/20	27	
	Confluence to lake	9/18	4,510	
Little Wenatchee River	Lake to hatchery rack	9/19	242	
Nason Creek	Cole's Corner to Wenatchee R.	9/26	16	
Wenatchee River	Outlet of lake to ½ mi. below	9/20	230	5,025
Little Wenatchee and White River	Hatchery take			2,064
				7,089

In an attempt to account for a greater share of the Rock Island counted bluebacks, an estimate based on averages was applied. The estimation (using average counts) of numbers of spawners in the Wenatchee system is based on the assumption that the total numbers of spawners utilizing a given stream section is equal to the average number of live fish in the stream during the spawning period multiplied by the ratio "time period live fish are in the stream" over, "average length of life of the fish after reaching the section." Algebraically,

$$R = M D / T$$

R equals the total number of spawners, M is the average number, D is the duration of period that live fish are present in the section, and T is the length of life of an individual fish after reaching the section. To evaluate this equation, the symbols M, D, and T must be given numerical value. The best estimate of M is the average of successive counts in each section. D is not known with precision, but can be estimated by the occurrence curves of the number of fish found in a section upon successive visits.

The 1947 occurrence curves from counts obtained in the Okanogan River and fitted by inspection, indicated that the length of the period during which fish were present was about 35 days (figure 7). In the absence of sufficiently complete data for the Lake Wenatchee drainage, this figure was used for that area also. For T, the stream life of the average blueback, no definite information is available for the Columbia River, but a period of 7 days has been estimated on the basis of tagging experiments at Karluk Lake, Alaska, and is here used as the best available substitute.

The value of D/T or 35/7 then becomes 5. When only one count was made, it was used as the average. This procedure produces counts of 34,710, 36,185, 2,925, and 17,495, for 1947, 1948, 1949, and 1951, which when added to those fish trapped and spawned by the hatchery, give totals of 38,615 or 48.4 percent of the 1947 Rock Island count, 40,350 or 47.7 percent of the 1948 count, 4,156 or 22.3 percent of the 1949 count, and 19,559 or 19.2 percent of the 1951 count. This is probably a better estimate of the spawners which utilized the Wenatchee area (table 3) than that based on maximum counts alone.

Thus estimates of numbers of spawners utilizing the Wenatchee region have been made. Their calculation is the first step in calculating the ratio of the number of spawners to the number of square yards of suitable spawning area available in this system. Further useful information was obtained from stream survey notes compiled by stream surveys of the Service. These surveys give the total number of square yards of available spawning gravel in the Wenatchee River system. Finally, information on the square yard requirement for each pair of spawning bluebacks was obtained from earlier work on this subject (Burner, 1951, p. 110). 4/

4/ 8.0 square yards given in above publicaton; used 8.4 which was obtained by Burner after a more complete analysis of his data.

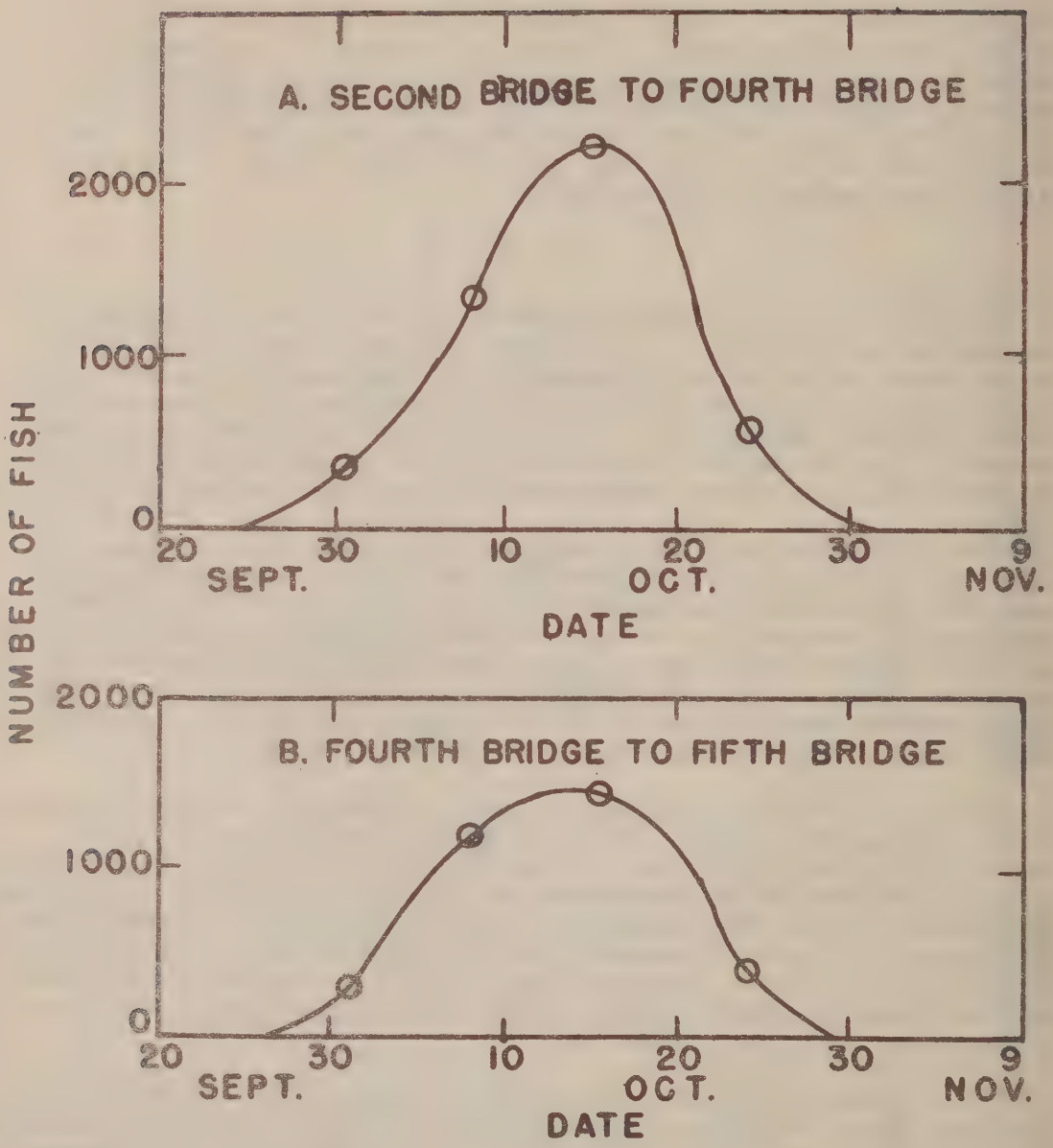

Figure 7. Occurrence curves from blueback spawning counts in the Okanogan River, 1947.

TABLE 3

DATA FROM SURVEYS OF BLUEBACKS SPAWNING IN INDIVIDUAL STREAM SECTIONS, 1947 - 1951

STREAM	SECTION	DATE	SURVEY	COUNT	AVERAGE	(X)5
1947						
White River	North Fork, 2 miles above confluence	9/24	1	58	58	290
White River	Confluence to lake	9/17-19	1	5,529		
		9/24-25	2	2,868	4,198	20,990
Little Wenatchee River	Hatchery racks to lake	10/10	1	1,122	1,122	5,610
Nason Creek	Lower 2 miles	9/22	1	482	482	2,410
Wenatchee River	Outlet of Lake Wenatchee to ½ mile below	9/22	1	1,082	1,082	5,410
					Total	34,710
1948						
White River	North Fork 2 miles above confluence	9/17	1	3,400		
		9/24	2	807	2,104	10,520
White River	Confluence to lake	9/15	1	1,445		
		9/21	2	3,871		
		10/4	3	862	2,059	10,295
Little Wenatchee River	Hatchery racks to lake	9/14	1	756		
		9/24	2	214	485	2,425
Little Wenatchee River	Above racks	9/22	1	1,945	1,945	5,835 1/
Nason Creek	Lower 2 miles	9/17	1	478		
		9/24	2	378	428	2,140
Wenatchee River	Outlet of Lake Wenatchee to ½ mile below	9/15	1	1,594		
		9/24	2	394	994	4,970
					Total	36,185
1949						
White River	North Fork 2 miles above confluence	9/8	1	0		
		9/14	2	0		
		9/20	3	192		
		9/27	4	265	114	570
White River	Confluence to lake	9/8	1	7		
		9/14	2	6		
		9/21	3	659		
		9/27	4	180	213	1,065
Little Wenatchee River	Hatchery racks to lake	9/7	1	158		
		9/14	2	122		
		9/20	3	248		
		9/27	4	30	140	700
Nason Creek	Lower 2 miles	9/8	1	0		
		9/14	2	70		
		9/21	3	41		
		9/27	4	54	41	205
Wenatchee River	Outlet of lake to ½ mile below	9/8	1	0		
		9/14	2	0		
		9/21	3	196		
		9/27	4	113	77	385
					Total	2,925
1951						
White River	North Fork 2 miles above confluence	9/20	1	27	27	135
White River	Confluence to lake	9/18	1	4510		
		9/26	2	1457	2984	14,920
Little Wenatchee River	Hatchery racks to lake, above racks	9/19	1	230	230	1,150
		9/19	1	12	12	60
Nason Creek	Lower 2 miles	9/26	1	16	16	80
Wenatchee River	Outlet of lake to ½ mile below	9/20	1	230	230	1,150
					Total	17,495

1/ This stream area was cut off for two weeks by hatchery racks so the factor of three was used.

Table 4 is a summary of the information showing the estimate by stream surveyors of the total number of square yards of suitable spawning gravels available for each section in the Wenatchee system, the number of bluebacks which can be accommodated, and the number of spawners in each section in 1947, 1948, 1949, and 1951. It can be seen that a total of 129,000 bluebacks could spawn in the area without crowding if they distributed themselves in proportion to area available. However, it will be observed in table 4 that some stream sections support nearly maximum populations while others remain only partially used. Altogether there is about seventy percent more suitable spawning area available than was used during the largest spawning concentration in 1948.

THE OKANOGAN SURVEYS

The Okanogan River system constitutes the second of the two major spawning and rearing areas for blueback salmon. In this system is Lake Osyoos, which extends north to south with approximately 4 miles in Canada and 4 miles in the United States, and the Okanogan River which flows through Lake Osoyoos. The major spawning takes place in a 20-mile stretch of the river above the lake (figure 8). The upper limit of spawning is the Oliver diversion dam, about 6 feet in height. There are no fish-passage facilities there.

Approximately the same procedure was used for counting the spawners in the Okanogan as was used in the Wenatchee area. Table 5 is a summary of Okanogan counts. Unfortunately, flooding conditions in 1948 made it impossible to make counts in most of the river area in that year. The best that could be done was to compare the areas tallied with those of 1947 and make an estimate of the remainder.

Using the average counts and applying the factor 5 as before provides estimates of 18,125 bluebacks in the Okanogan in 1947, 35,875 in 1948, 310 in 1949 and 12,240 in 1951. The 1949 light run in this section is easily explained in view of the predominance of a 4-year cycle in bluebacks. In the Grand Coulee fish-transportation program no 1941 adult blueback or brood of that year were planted in Lake Osoyoos and only 47 fish (possibly made up of 3-year and 5-year fish) were seen there in 1945. The 1949 run resulted from this 1945 stock.

Referring to spawning-gravel requirements, table 6 gives the number of square yards available compared with the number of spawners during each of the 4 years. Note that this spawning area could accommodate many more fish than our maximum estimate of 1948. That was also the general conclusion derived from direct observation of the spawning beds.

TABLE 4

Calculated Estimates of Available Square Yards of Suitable Spawning Gravel for Blueback Salmon in Various Stream Sections of the Lake Wenatchee Area Compared to Population Estimates of Those Areas in 1947 - 1951

Stream	Section	Sq. Yds. of Suitable Spawning Gravel	No. of fish which could be accommodated (using 8.4 sq. yds. per pair)	Estimated Spawning Populations 1947	1948	1949	1951
White River	Lower 2 miles of North Fork	50,000	12,000	290	10,520	570	135
White River	Confluence of North and South Fork to lake	154,000	37,000	20,990	10,295	1,065	14,920
Little Wenatchee River	Hatchery Racks to lake about 2 miles	36,000	9,000	5,610	2,425	700	1,150
Little Wenatchee River	Hatchery Racks to Falls Area	236,000	56,000	1/	5,835	1/	60
Nason Creek	Lower 2 miles of stream	30,000	7,000	2,410	2,140	205	80
Wenatchee River	Outlet of lake to ½ mile below	32,000	8,000	5,410	4,970	385	1,150
	Total	538,000	129,000	34,710	36,185	2,925	17,495

1/ No fish were released beyond hatchery racks during season.

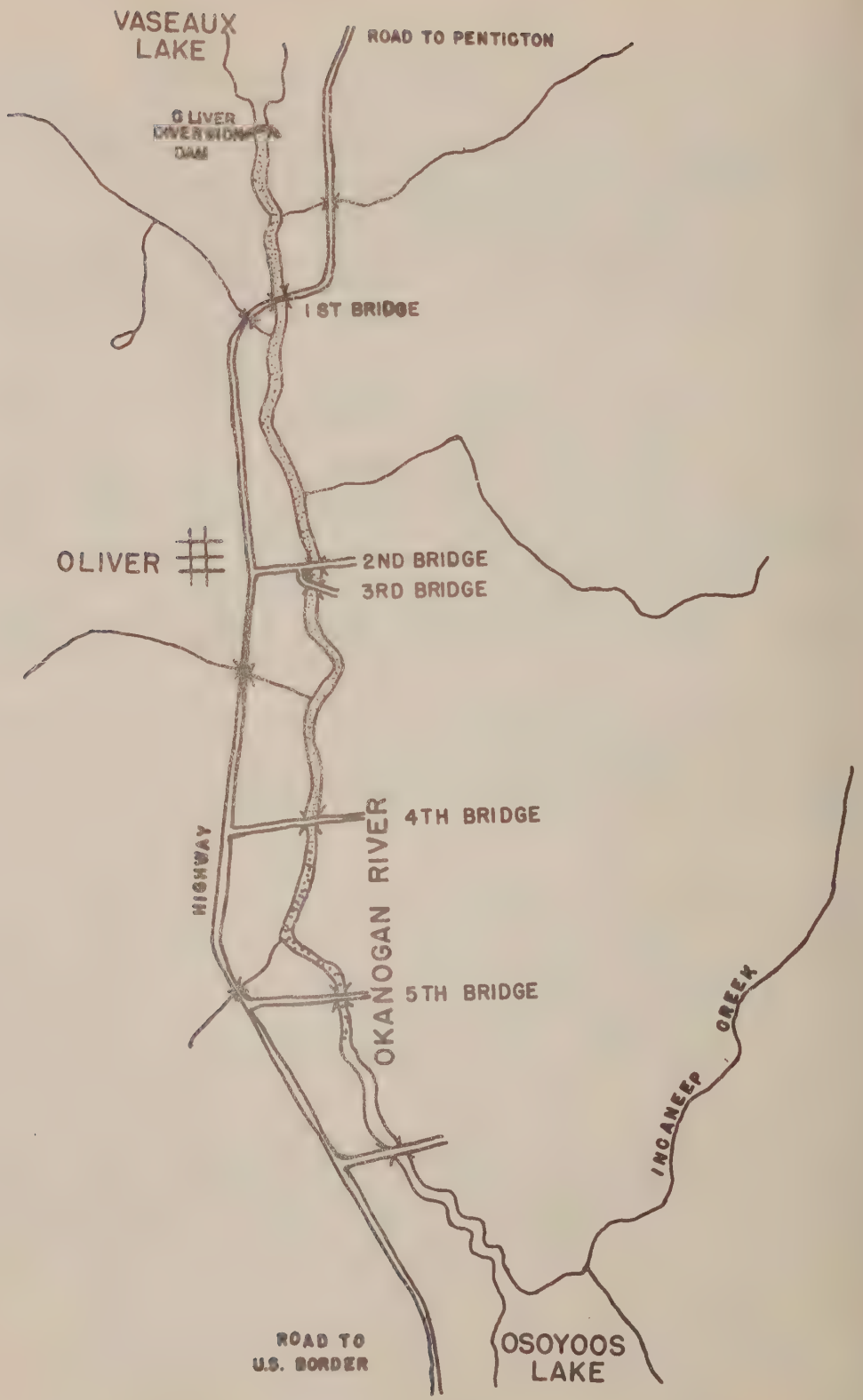

Figure 8. Diagrammatic map of the principle blueback salmon spawning areas of the Okanogan River System.

TABLE 5

DATA FROM SURVEYS OF BLUEBACK SPAWNING IN STREAM SECTIONS OF THE OKANOGAN RIVER, 1947 - 1949 and 1951

STREAM SECTION	DATE	SURVEY	COUNT	AVERAGE	(X)5
1947					
Diversion dam to first bridge	10/2	1	850		
" " " " "	10/9	2	1,023		
" " " " "	10/16	2	378	750	3,750
First to second bridge	10/2	1	341		
" " "	10/8	2	1,234		
" " "	10/15	3	1,047	874	4,370
Second to fourth bridge	10/1	1	313		
" " "	10/8	2	1,375		
" " "	10/15	3	2,249		
" " "	10/24	4	555	1,123	5,615
Fourth to fifth bridge	10/1	1	254		
" " "	10/8	2	1,171		
" " "	10/15	3	1,474		
" " "	10/24	4	424	831	4,155
Fifth bridge to lake	10/16	1	47	47	235
				Total	18,125
1948					
Diversion to first bridge	9/30	1	1,084		
" " " "	10/12	2	1,154		
An average based on ratio with 1947 counts			7,175 1/		
				Total	35,875
1949					
Diversion dam to first bridge	9/29	1	32		
" " " " "	10/5	2	83		
" " " " "	10/20	3	0	38	190
First bridge to fifth bridge	9/28	1	50		
" " " " "	10/5	2	22		
" " " " "	10/20	3	0	24	120
				Total	310
1951					
Diversion dam to first bridge	9/26	1	489		
" " " " "	10/4	2	4,172		
" " " " "	10/10	3	1,795		
" " " " "	10/17	4	865	1,830	9,150
First to second bridge	9/25	1	17		
" " " "	10/3	2	376		
" " " "	10/9	3	1,065		
" " " "	10/16	4	450	477	2,385
Second to fourth bridge	9/25	1	7		
" " " "	10/3	2	112		
" " " "	10/9	3	354		
" " " "	10/16	4	64	134	670
Fourth bridge to lake	10/4	1	11		
	10/10	2	3	7	35
				Total	12,240

1/ Extremely high water in 1948 limited surveys to only a portion of the area. The areas that could be counted were compared with counts of 1947 and a similar ratio applied to obtain an estimate for 1948.

TABLE 6

CALCULATED ESTIMATES OF AVAILABLE SQUARE YARDS OF SUITABLE SPAWNING GRAVEL FOR BLUEBACKS IN THE OKANOGAN RIVER COMPARED TO POPULATION ESTIMATES DURING 1947-51

Year	Number of Fish	Square yards of gravel utilized using 8.4 sq. yds. per pair	Square yards of potential gravel available.
1947	18,125	76,000	601,000
1948[2/]	35,875	151,000	601,000
1949	310	1,300	601,000
1951	12,240	51,000	601,000

Although the seeding of spawning gravels continues to improve as exemplified by the escapements past Rock Island Dam, the survival of the young fish plays an important part in determining the ultimate return and this can vary within wide limits. Exceptionally cold weather and reduced flows can damage the eggs of alevins by freezing and dehydration. Ice jams may scour out the gravel before the young fry are in the free-swimming stage.

During the winter of 1947-48 information was obtained concerning the early life history of the bluebacks in the Wenatchee and Okanogan systems. Redds were selected and marked with an iron pipe driven into the stream bed. Periodic inspections were made during the winter while the spawn was in the gravel. A very small, spoon-like blade was used on an ordinary shovel handle and a fine-mesh hand-net held directly downstream from where the shovel was thrust into the gravel. The information derived from this study is shown in tables 7 and 8.

As a result of the spawning-bed inspections we thought that the young of the 1947 brood fared well with one exception. On March 3, 1948, dead eggs were found in the Okanogan River. On further investigation it was found that the river flow had been shut off at the control gate upstream just below Lake Okanogan for about a week while the dam and fishways were being rebuilt at Zosel Dam, Oroville, Washington. This probably was a contributing factor which resulted in smaller spawning counts in the Okanogan in 1951, despite larger Rock Island counts. No nest inspections were carried on during the winter of 1948, but it is a matter of record that the blueback areas were subject to exceptionally cold weather during that winter.

2/ Based on a ratio with 1947 counts.

TABLE 7

OBSERVATIONS OF A BLUEBACK SALMON NEST LOCATED IN THE WENATCHEE RIVER APPROXIMATELY ONE-HALF MILE BELOW LAKE WENATCHEE DURING THE WINTER 1947 - 1948

Visit No.	Date	Weather	Air Temp.F.	Water Temp.F.	Sample Condition	River Condition
1	12/9	Clear	44.0°	43.0°	9 eyed eggs	Nest covered with one foot of water
2	12/16	Snowing	34.0°	42.5°	11 eyed eggs	Same
3	12/23	Snowing	32.0°	34.5°	2 alevins, 2 eyed eggs	Same
4	1/5	Cloudy	35.0°	40.0°	5 in alevin stage	Low, but nest covered
5	1/12	Clear	17.0°	38.5°	3 in alevin stage	Same
6	1/29	Cloudy	28.0°	37.0°	5 in alevin stage	Water level up slightly
7	2/13	Part Cloudy	43.5°	38.5°	7 in alevin stage	Low but nest covered
8	2/18	Cloudy	38.0°	37.0°	4 fry egg-sac about absorbed	Nest covered with about one foot of water - no ice.
9	2/26	Snow	36.0°	38.5°	3 fry have no egg-sac, 2 with egg-sac.	Same
10	3/5	Cloudy	44.0°	43.0°	2 fry well advanced 2 with presence of egg-sac	Same
11	3/15	Fair	50.0°	45.0°	3 fry well advanced 3 have evidence of yolk sac	Same Free swimming fry seen in shallow eddies
12	3/29	Fair	48.0°	47.5°	7 fry all in well advanced stage were all that was found in the entire nest.	Same

TABLE 8

OBSERVATIONS OF A BLUEBACK SALMON NEST LOCATED IN THE OKANOGAN RIVER APPROXIMATELY ONE QUARTER MILE ABOVE FIRST BRIDGE BELOW OLIVER DIVERSION DAM NEAR OLIVER, B.C. DURING WINTER 1947 - 1948

Visit No.	Date	Weather	Air Temp.F.	Water Temp.F.	Sample Condition	River Condition
1	12/18	Fair	45.0°	37.5°	8 eyed eggs	Up approximately one foot since spawning
2	12/30	Clear	30.0°	36.0°	2 in alevin stage 2 eyed eggs	Same
3	1/13	Clear	27.0°	34.0°	6 in alevin stage	Up another 8"
4	1/28	Clear	29.0°	34.5°	4 in alevin stage	Up another 4"
5	2/20	Snowing	35.0°	34.0°	5 fry egg-sac stage	Same level as spawning time
6	3/3	Clear	39.0°	39.0°	5 fry egg-sac stage	River level below that of spawning time
7	3/16	Fair	46.0°	43.0°	10 fry egg sac stage	Up to spawning level
8	3/31	Fair	56.0°	48.0°	9 fry egg-sac half absorbed	Same Water badly silted
9	4/14	Fair	55.0°	47.0°	Only 2 fry left in nest. Fry in well advanced stage	Same

Seeding of the spawning gravel in 1949 appeared to be successful. Since this was a small run it gave the 1949 adult spawners a selection of the best spawning gravel with a minimum possibility of crowding. The 1949 run did not fare well during the upstream migration however. Only 40 percent of the bluebacks were counted past Rock Island Dam (table 1), and only a small portion of the remaining population reached the spawning grounds above.

Seeding of the spawning grounds in 1951 probably will not be as successful as Rock Island counts indicate because of injuries which may have resulted from partial blockage and delay at McNary Dam. It is estimated that 8 percent of the females had internal injuries which affected the ripening of part or all of the eggs. Discussion on this subject will follow. Spawning conditions, otherwise, were favorable for blueback that survived without injury during the upstream migration of 1951.

SURVIVAL IN THE REARING LAKE

Bluebacks normally remain during their first year in Lake Wenatchee or Lake Osoyoos and migrate seaward in their second year. Other species compete with them for food and predatory fish reduce their number during the time they remain in the lakes. Experimental predatory-fish sampling by means of gill-nets was done in Lake Wenatchee during 1949-51 to determine what species inhabited the lake and to what extent they were preying on the Kokanee (landlocked bluebacks) and the young sea-run bluebacks which cannot be distinguished from each other. Four species, squawfish (Ptychocheilus oregonensis), suckers (Catostomus species), Dolly Varden (Salvelinus malma), and whitefish (Prosopium species), were taken by gill-net. Two species which were found to contain identifiable O. nerka (bluebacks or kokanee) in their stomach contents, were squawfish and Dolly Varden trout. A total of 113 squawfish examined contained 12 O. nerka plus a number of sculpin, lampreys, and unidentified partially digested fish. Thirty-nine Dolly Varden charrs contained a total of 26 O. nerka in their stomachs.

R. E. Foerster and W. E. Ricker (1942) stated that the principal food of squawfish in the Cultus Lake, British Columbia area is young sockeye salmon. Their predator-control program conducted by means of gill-netting is reported to have benefited the fishing industry by thousands of dollars.

FUTURE OF THE RUNS AND RECOMMENDATIONS

The Columbia River blueback salmon runs face difficulties. The Canadian government is planning a flood-control project which will destroy more than 75 percent of the spawning area available to bluebacks in the Okanogan region. The stream which now winds through the Okanogan valley will be straightened by channelizing and will have a series of low dams at intervals along its course. This will be for the purpose of drawing off water more rapidly from Lake Okanogan which lies to the north. Thousands of square yards of suitable spawning rubble will thus be bypassed by the new channel.

A plan was proposed by J. T. Barnaby of the Fish and Wildlife Service for extending the migration of blueback salmon to compensate for the loss of spawning area resulting from the Canadian flood-control program. The plan, however, was not accepted by the Canadians. It would have opened several lakes and streams which were formerly utilized by the bluebacks. Vaseaux, Skaha and Okanogan Lakes, nine possible streams, and an unestimated amount of lake-shore spawning area would have become available. 5/ These areas are shown in figure 9.

The plan proposed would have involved (1) the construction of fish ladders at Oliver Diversion Dam, Okanogan Falls, and Lake Okanogan outlet, plus a series of small ladders over drop sections planned in the channel, and fish screens to protect fingerlings from becoming diverted into irrigation ditches, and (2) relocation of the present runs upstream into the new rearing area. From past experience it is regarded as very doubtful whether the salmon would make a prespawning migration beyond Lake Osoyoos. The theory that bluebacks remain in the lake and proceed upstream just before spawning is substantiated by earlier investigators who have stated that sockeye (blueback) salmon not only return to their own river basin at maturity but predominantly return to the particular part of the river basin in which they were reared as fingerlings (Gilbert 1917, p. 61). The run would be trapped and hauled by truck to the new lakes. The most logical trapping point is at Zosel Dam located at Oroville, Washington.

One disadvantage to be taken into account when considering the extension of spawning grounds was the lack of protection of blueback salmon in Canadian waters. More rigidly enforced laws are needed. In the past, snagging, gaffing, and even gill-netting have been consistently in evidence in this area. These activities are undoubtedly responsible for the loss of a considerable number of spawners each year and would be even more serious if the fish had a longer migration route through relatively constricted channels to the upper region. 6/

A secondary proposal by Barnaby will allow the blueback run to pass over drop sections to be constructed in the channel. Small fishways over these will make it possible for the salmon to pass upstream to the upper portion of their present spawning area not altered by the flood control project.

The importance to future blueback runs of maintaining a Lake Osoyoos spawning and rearing area may be deomonstrated by comparing the plankton populations of Lake Osoyoos with Lake Wenatchee. 7/ Young blueback salmon are principally plankton feeders.

5/ This system of lakes at one time produced a substantial part of the entire blueback population of the Columbia River (Fish and Hanavan, 1948, p.23).

6/ "Interim report on Okanogan River, British Columbia". J. T. Barnaby, mimeographed report by the U.S. Fish and Wildlife Service. October 1950, 5 pp.

7/ Lake Wenatchee would probably have to support the entire natural spawning run of blueback salmon if it became necessary to abandon Lake Osoyoos.

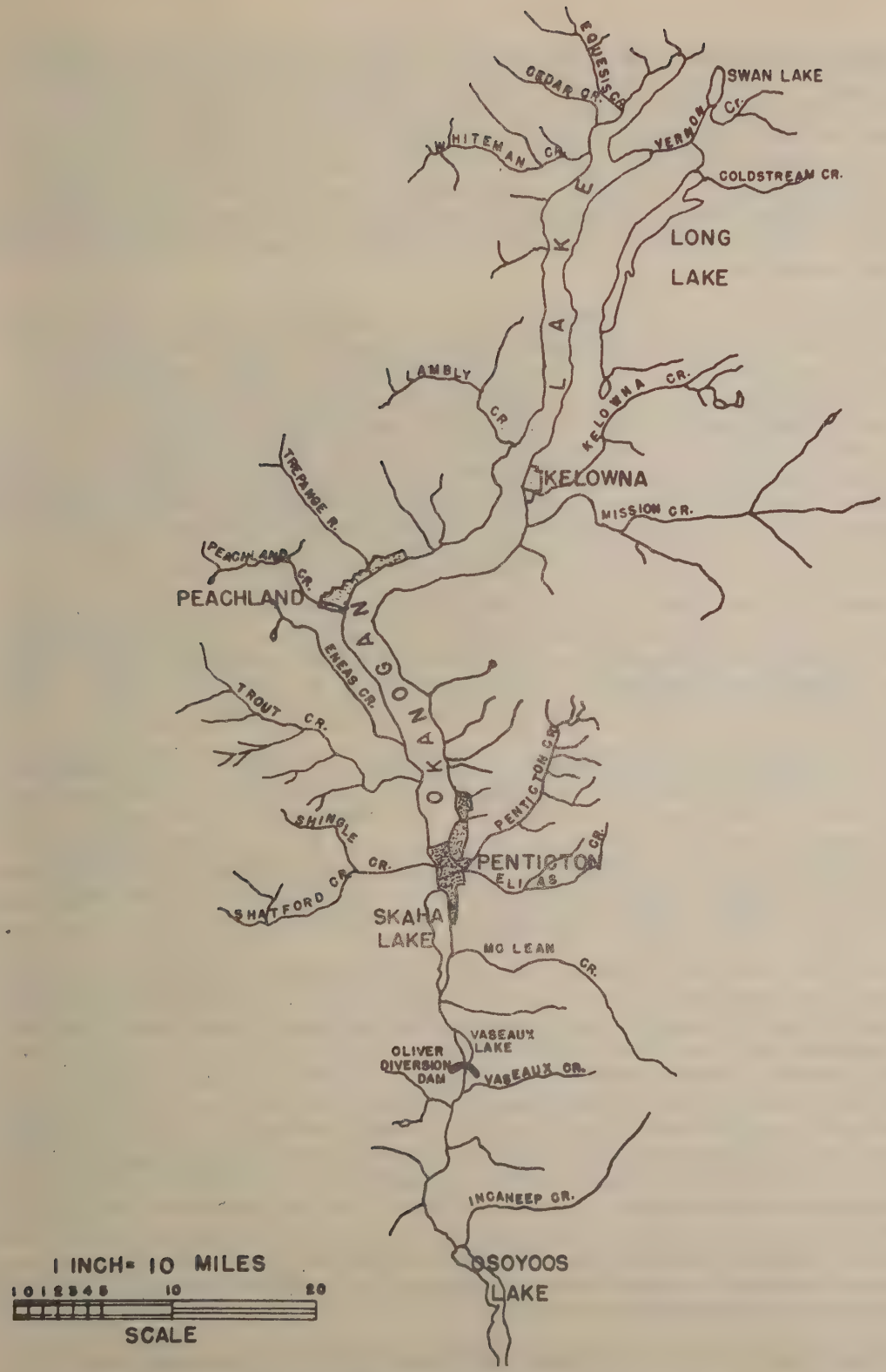

Figure 9. Map of upper Okanogan region showing possible spawning area for blueback salmon.

During the months of September and October 1939-40, plankton samples were taken at regular intervals from the two lakes. A standard-type plankton net with a 3-3/4-inch orifice, a brass collection bucket, and body of No. 20 silk bolting cloth was used. In Lake Osoyoos, 16 vertical plankton hauls of 86-foot average depth produced an average of 0.450 c.c. of plankton material. In Lake Wenatchee, 14 vertical hauls of 142-foot average depth collected 0.191 c.c. of material. Surface tows provided an average of 0.67 c.c. of plankton per 100 yards in Lake Osoyoos to 0.18 c.c. in Lake Wenatchee.

A superiority of more than 2 to 1 in plankton for Lake Osoyoos demonstrates the desirability of that lake as a rearing place for blueback salmon. This was also borne out by observations. Landlocked blueback (kokanee) in Lake Wenatchee are dwarfed, averaging 5 inches in length, whereas in Lake Osoyoos they range from 8 to 14 inches. This could in part be a result of population pressure, but it could well be a direct result of difference in plankton production. The shallow marginal area of Lake Osoyoos, the warm climate, and the surface drainage of large lakes upstream all lend themselves to good food production. Steep slopes and colder temperatures of Lake Wenatchee are not as favorable for this purpose.

Owing to the productivity of the Lake Osoyoos region, the Okanogan blueback runs should be preserved if at all possible. This is especially so in light of the possibility that Lake Wenatchee, already taxed by population pressue and having limited sources of food, could not support these additional blueback stocks as satisfactorily as the Okanogan region.

Such programs as the Okanogan flood-control project raise a question about the wisdom of having the spawning area for bluebacks remain exclusively within the two areas now utilized. Any temporary or permanent obstruction occurring in the stream can virtually wipe out a migration into that particular area. Obstructions of this type have occurred on several occasions. For example, during low-water years there are dry stretches[8/] in the Wenatchee River which have delayed and jeopardized the runs.

Another example of how a temporary or permanent obstruction can affect the runs was provided at the time of construction of McNary Dam located on the main Columbia River between Bonneville and Rock Island Dams. Two of the fishways provided there were put out of operation in 1951 during the spring freshet. The migration was delayed and the bluebacks were subjected to high-velocity flows. Some salmon were hoisted over the structure by means of a large dip-net. Considerable numbers eventually found their way through the navigation locks. Fish counters at Rock Island Dam reported that approximately 25 percent of the bluebacks bore injuries. This percentage was never so high in previous years. On the Wenatchee River at Dryden Dam approximately ten percent of the passing bluebacks had deep head and back injuries and hatchery personnel who took spawn in the Wenatchee area reported eight percent of the females had damaged ovaries. This affected ripening of all or part of the eggs.

8/ Power dams located at Dryden and Tumwater during low water years such as experienced in 1944-45 may draw virtually all of the stream flow, preventing or delaying the salmon migrations (Fish and Hanavan 1948, pp. 47 and 55).

There is urgent need to reduce the possibility of large percentages of blueback salmon being isolated by construction of high dams such as the proposed Priest Rapids Dam situated between Rock Island and McNary Dams, or injured and delayed as at McNary Dam and at Dryden and Tumwater Dams during low-water periods. This could be accomplished by surveys and exploratory planting of young bluebacks to determine what other lakes and streams may be utilized for blueback salmon spawning in the event that those presently in use should become isolated by river utilization for other purposes.

With the present increase in the runs, larger numbers of young fish are available for experimental planting. A possibility for a test of this kind would be the Yakima system where blueback runs have been eliminated by lack of fishways and fish screens at water diversions--conditions which have since been improved by extensive construction of these devices. In the Yakima system such lakes as Keechelus, Kachess, Cle Elum, and Bumping are reported to have been at one time natural rearing areas for bluebacks. These lakes are presently dammed at their outlets and used for water storage. The water is released in accordance with irrigation demands. The most readily adaptable of these is Bumping Lake which has a 45-foot dam and a reasonably constant year-round flow. It is possible that alterations of flow regulation (such as those proposed for the Trinity River, California, Moffett and Smith 1950, p. 58) could be made in one or two of the other lakes to make them suitable for blueback salmon.9/ (These flow regulations and related temperatures will be studied further.) A planting of bluebacks in Bumping Lake was made in 1942 with a recovery of 0.008 percent10/ from a 25,000-fish planting as shown by returns of marked individuals. It is felt that more experiments should be conducted in Bumping Lake, as well as some in other lakes. If a good return were experienced, the bluebacks could be trapped and hauled over Bumping Lake Dam until proper fishways were warranted.

Another possibility is Palmer Lake which is on the Similkameen River, a tributary of the Okanogan River. Six miles from its confluence with the Okanogan River, the Similkameen River has a power dam 65 feet high that has never been equipped with a fishway. Palmer Lake lies farther upstream but is all within the United States and has been regarded as being well adapted to the production of blueback salmon. 11/

9/ The level of abundance of the Yakima River anadromous-fish populations could be raised substantially if adequate flows were provided during periods of fish migration, if certain improvements were made to fishways at Prosser, Sunnyside and Wapato Dams, and if certain other improvements in the interest of fish life were effected. (Corps of Engineers 1948, p. 68).

10/ This extremely low percentage of recovery could well be a result of introducing Quinault sockeye salmon which are not endemic to the Columbia River system.

11/ "A report of the preliminary investigations into the possible methods of preserving the Columbia River salmon and steelhead at the Grand Coulee Dam." Mimeographed report by the Washington State Department of Fisheries, 121 pp, January 1948.

SUMMARY AND CONCLUSIONS

This study was begun in 1947 when the largest blueback salmon spawning escapement since 1938 brought concern as to whether or not remaining spawning and rearing grounds were adequate. Suitable blueback salmon spawning areas have been greatly reduced by the construction of water-use projects.

Paralleling the gradual loss of rearing areas available has been a general downward trend in the commercial catches. An all-time low was experienced in 1945. This has been followed by increased runs in recent years, most noticeably at Rock Island Dam where a counting station has been maintained and where an estimate of the spawning escapement can be made.

The main objectives of the 1947-49 and 1951 blueback studies were to determine the success of natural spawning under anticipated conditions of overcrowding. A system based on averages was applied to the counts which gave estimates for total spawning populations. Relating these estimates to data obtained on the number of square yards of gravel available as determined by stream surveys and applying a given square-yard gravel requirement for spawning bluebacks provided data to support the conclusion that there was no overcrowding, and this conclusion was borne out by observations. In some instances there were concentrations of fish on certain spawning riffles while other apparently suitable gravels remained unoccupied. It has been shown that the available gravel was more than adequate for the number of spawners in the Wenatchee system. The presently available spawning grounds in the Okanogan system could support a run approximately four times the number of fish estimated in the run of 1948.

Regular examinations of sample nests were made during the winter of 1947-48 to observe progress of the young bluebacks and study environmental conditions.

A study of predators in Lake Wenatchee revealed that young salmon were being preyed upon by squawfish and Dolly Varden trout.

Owing to imminent construction of additional dams within the Columbia River system it is recommended that new waters be experimentally planted with blueback salmon. Data from this type of research would be useful in future planning for development of Columbia River blueback salmon runs.

Prospects for future Columbia River blueback runs depend on a number of factors. The dangers to the developing eggs of severe winter conditions, the losses of young due to predators and competitors in the rearing areas, and unscreened water diversions along their downstream migratory routes, the mortality of upstream migrant adults due to low water and high temperatures, all have been discussed. Another factor which will affect the future escapements is the intensity of the commercial fishery in the lower river. Good catches will undoubtedly attract more fishermen to the blueback fishery and thereby increase the fishing intensity for the blueback salmon, allowing a correspondingly smaller spawning escapement. The 1950 and 1951 escapements show a continued increase, with the Rock Island count of 1950 exceeding its cycle year by 5,018 fish and the 1951 count establishing an 18-year record of 101,682 blueback salmon over the dam.

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